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Effect of buffer gases on the performance of SO_2 trace measurement based on photoacoustic spectroscopy

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HIGHLIGHTS

- In this experimental work a laser photoacoustic spectrometer designed and fabricated.
- Sensitivity of system for SO_2 and NO_2 are 353 ppb and 963 ppb respectively was measured.
- Variation of PA signal and corresponding resonant frequency were measured in various pressures.
- PA signals for Helium buffer gas case was the lowest signal.

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ABSTRACT

In this experimental work a laser photoacoustic spectrometer designed and fabricated. System sensitivity for detection of SO_2 and NO_2 was measured. Resonance frequency variation versus pressure increase of Nitrogen, Argon, Helium and Air buffer gases was studied. Results show that, sensitivity of system for SO_2 and NO_2 are 353 ppb and 963 ppb respectively. It was shown that resonance frequency for Nitrogen, Argon, and Air buffer gases was not noticeably varied by buffer gas pressure increasing, but for Helium, resonance frequency not only is not in range of three other gases, but also grows by pressure increasing. The system noises were damped preparing two buffer chambers.

1. Introduction

The photoacoustic (PA) effect in solids was discovered by Bell in 1880 [1]. It was soon realized that the same effect exists in liquids and gases as well. Also in these first experiments, resonant amplification of the photoacostic signal was discovered [2]. However, due to the lack of proper instrumentation (such as light sources, microphones and electronics), the PA effect was almost completely forgotten for more than half a century. Finally, in 1938, Veingerov introduced a PA system based on a blackbody infrared source and a microphone for analysis of gas mixtures [3]. In the 1960s, an important breakthrough was achieved by the first use of a laser in PA gas detection compared to conventional light sources [4]. The lasers have superior beam quality and narrow bandwidth providing high power coherent beam. Trace gas analysis was targeted first by the pioneering work of Kreuaer [5]. A PA cylindrical cell was employed to operate in a resonant mode by tuning the laser modulation frequency to one of the acoustic resonances. It was first introduced by Dewey et al. [6] and Kamm [7]. In the 1970s and 1980s photoacoustic gas detection became popular in various spectroscopic applications. High sensitivities were achieved by PA systems using mid and far infrared gas lasers such as CO and CO_2 lasers. The outstanding features of the PA cell consist of the small size, simplicity, and robustness which can be fully exploited when it is combined with a suitable laser source. Recently, the development of diode lasers increasingly has influenced on the application of compact PA gas analyzers [8].

Applications of laser PA spectroscopy include concentration measurements and trace gas analysis, accurate determination of thermophysical properties, detection of dynamic processes such as mixing of gases or chemical reactions, relaxation processes, spectroscopic experiments, measurement of aerosols. Trace-gas detection techniques are important for applications such as breath diagnostics, security and workplace surveillance, air-quality measurements, atmospheric monitoring (more than 250 molecular gases of environmental interest can be identified and measured quantitatively, e.g. CO_2, H_2O, O_3, different hydrocarbons, etc.). The laser based instruments can also be used for detection of a wide variety of industrial gases, including benzene, hydrogen

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